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ORIGINAL RESEARCH

THERE ARE NO BIOMECHANICAL DIFFERENCES BETWEEN RUNNERS CLASSIFIED BY THE FUNCTIONAL MOVEMENT SCREEN

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ABSTRACT

Background: Running has been one of the main choices of physical activity in people seeking an active lifestyle. The Functional Movement Screen (FMS™) is a screening tool that aims to discern movement competency.

Purpose: The purposes of this study were to compare biomechanical characteristics between two groups rated using the composite FMS™ score, and to analyze the influence of specific individual tests. The hypothesis was that the group that scored above 14 would demonstrate better performance on biomechanical tests than the group that scored below 14.

Study Design: Cross-Sectional Study.

Methods: Runners were screened using the FMS™ and were dichotomized into groups based on final score: Functional, where the subjects scored a 14 or greater (G≥14, n = 16) and dysfunctional, when the subjects scored less than 14 (G< 14, n = 16). All runners were evaluated using measures for flexibility, postural balance, muscle strength, knee dynamic valgus during forward step down test and time for the electromyographic response of the transversus abdominis and fibularis longus muscles. All data were analyzed with SPSS ($p \leq 0.05$) and the index of asymmetry (IS) was calculated with the mean score of nondominant limb divided by the mean score of the dominant limb, multiplied by 100.

Results: There were no statistically significant differences in flexibility, muscle strength, knee dynamic valgus, or myoelectric response time of the transversus abdominis and long fibular muscles. Index of asymmetry (IS) of global stability was 3.26 ± 26.79% in G≥14 and 31.72 ± 52.69% in G < 14 ($p = 0.02$). In-line lunge and active straight-leg raise tests showed no significant difference between the groups ($p > 0.05$).

Conclusions: Overall, there were no biomechanical differences between the groups of runners as classified by the FMS™. In addition, in-line lunge and active strength-leg raise tests did not influence on the FMS™ final score.

Level of Evidence: 2b

Key words: Electromyography, fundamental movements, running

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INTRODUCTION

Running is a popular sport in world because it is associated with a healthy life style, reduction of cardiovascular risk factors, and is easy to do and can be done anywhere. However, a runner needs to have knowledge about running-related injuries and risk factors for injury in order to participate in this sport safely. The incidence rates of injury in runners ranged 2.5 to 12.1 injuries per 1000 hours of running. The highest incidence running-related musculoskeletal injuries among runners are patellar tendinopathy (5.5%-22.7%), medial tibial stress syndrome (9.1%-19.0%), Achilles tendinopathy (13.6%-20.0%), plantar fasciitis (4.5%-10%), patellofemoral syndrome (5.5%), and iliotibial band syndrome (1.8%-9.1%).[1] Researchers indicate that factors such as deficits in postural balance, flexibility, hamstring/quadriceps ratio and activation of stabilizing muscles of the lumbar spine (such as the transversus abdominis), hip stabilizers (*i.e.*, gluteus medius) and ankle stabilizers (*i.e.*, fibularis longus), are related to the high incidence of these injuries.[1-6]

Good performance on functional assessment tools or screens has been associated with lower risk of injury in runners.[7-9] The Functional Movement Screen (FMS™) is one such screening system used to evaluate the dynamic capacity of individuals in specific movements that require balance, mobility and stability, comparing the performance of the runners above and below of 14 cut-off score. The FMS™ consists of seven fundamental movements that are graded from 0 to 3 according to the performance in the execution of each movement; where a score of three means satisfactory movement competency, a score of two means that the person is able to complete the movement but with compensation, a score of one means that the person is unable to complete the movement pattern and a score of zero if at any time during the testing the person has pain. According to the final score, an individual's results can be dichotomized as satisfactory movement competency (*i.e.*, scores above 14) or unsatisfactory movement competency (*i.e.*, scores below 14). According to these principles, it is assumed that individuals with optimal functional movement patterns might exhibit symmetry in variables such as strength and posture stability, good measures of flexibility, and effective activation of stabilizing muscles. In contrast, individuals with dysfunctional movement patterns might exhibit asymmetries in variables, decreased flexibility, and difficulty with effective recruitment of muscles used to stabilize the body.[10-13]

The purposes of this study were to compare biomechanical characteristics between two groups of runners rated using the composite FMS™ score, and to analyze the influence of specific individual tests. The hypothesis was that the group that scored above 14 would demonstrate better performance on biomechanical tests than the group that scored below 14.

METHODS

A cross-sectional study was conducted with 32 runners in the Human Motion Analysis Laboratory of Department of Physical Therapy at the Federal University of Ceará. In order to be included, runners had to maintain a weekly workout routine of a minimum volume of 20 km per week and a minimum frequency of twice per week. Participants had to be between 18 and 60 years of age, and they could not have any diseases of the cardiorespiratory system, such as uncontrolled hypertension, angina, or have acute musculoskeletal pain. All subjects signed the informed consent and submitted to an interview, to identify their age, gender, weight, height, sports practice time, training volume and presence of injury over the prior year. This study was approved by the Institutional Human Research Ethics Committee (protocol number #208.176)

OUTCOME MEASURES

Functional Movement Screen (FMS™)

The FMS™ is a screening tool used to analyze fundamental patterns of movement. It consists of seven basic movements that require balance, mobility and stability: Deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise (ASLR), trunk stability push-up, rotatory stability. The assessment followed the order described by the authors of the method, and each movement was scored according to the criteria described by them, where each activity could be attempted three times, and were graded from 0 to 3. Zero (0) indicated pain during execution, one (1) indicated that the individual was unable to perform the movement, two (2) suggested the individual was able to perform the movement with some compensation, and three (3) suggested the subject was capable to perform the full movement without any compensations. At the end, scores were summed in order to obtain the total score (composite score), which has a maximum of 21 points. If there was a different score on each limb for a bilateral test, the lower of the two scores was used in the composite score. Individuals with total score lower than 14 points were placed in a group defined by the authors as functional (Group - G<14), and those with total score of 14 or higher were placed in a group defined by the authors as dysfunctional (Group - G≥14).[14,15] The participants were assessed by the same examiner, who was blinded from performance on the other tests.

Flexibility

Flexibility was evaluated with the sit and reach test.[16] This is performed with the patient seated, with hips flexed, knees extended and foot touching the anterior surface of the bench. The participants were instructed to move the bar as far as possible by flexing the trunk and keep the position for three seconds. The distance was measured in centimeters. Three attempts were performed and the highest value was considered for analysis.[17]

Postural Balance

Postural balance was evaluated using Biodex Balance System® (BBS®).[18] This device measures the degree of sway on two axes (anterior/posterior and medial/lateral) during testing.[19] The displacement of the center of gravity in both anterior/posterior and medial/lateral directions were analyzed as well as the overall displacement, which is a measurement obtained considering both. The protocol required one-legged stance and the athletes were positioned on the platform with tested the knee held at 10° of flexion and contralateral knee flexed to 90°. Athletes were instructed to remain steady during the test. This assessment was repeated three times for each limb and lasted for 20 seconds with 10 seconds of interval time, and average was utilized.[20] The Overall Stability Index, Antero-Posterior Stability Index, and Latero-Medial Stability Index (as calculated and provided by the BSS) were assessed and considered as outcome measures.

Myoelectric response time of the TrA/internal oblique (TrA/IO) muscles

Surface electromyography Miotool 400 (Miotec®, Porto Alegre/RS, Brazil) was used to evaluate the difference in activation time between the fibers of the anterior fibers deltoid and the TrA when a rapid flexion motion of the shoulder was conducted (anticipatory contraction mechanism). Skin preparation and electrode placement were conducted following the recommendations of the SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles).[21] A pair of electrodes was placed in a horizontal position: 20 mm medially and inferiorly the anterior superior iliac spine (ASIS) to evaluate the TrA muscle, and other pair was placed to two inches below and forward from the acromion, to evaluate the deltoid muscle. The distance between the centers of the electrodes was 20 mm, and the side evaluated was always the dominant one. The reference electrode was placed on the elbow of the dominant arm.[22,23]

Athletes were verbally asked to flex the shoulder three times as quickly as possible to 90°.[24] The participants were allowed to execute two to five repetitions of training in predetermined distances and speeds to familiarize them with the movement. The task was considered appropriate when the individual was able to contract the TrA muscle before or at the same time as the deltoid muscle.[24] Electromyographic signals were sampled at a frequency of 2000 Hz and filtered with a band-pass range of 20-450 Hz.

Myoelectric response time of fibularis longus muscle

In this test, the same surface electromyography unit (Miotec®, Porto Alegre/RS, Brazil) was used to identify the reaction time of the fibularis longus muscle following an inversion perturbation. If the reaction time is higher than 90 ms, there is a greater risk for ankle sprain.[25] The standards of the SENIAM were followed as in the previous electromyographic examination. The pairs of electrodes were placed in the upper third of the distance between the head of the fibula and the lateral malleolus (fibularis longus muscle) and on the fifth metatarsal (for vibration assessment only). The reference electrode was placed in the lateral epicondyle of the humerus. The assessment was conducted using the dominant limb.[21] The athlete was positioned in one-legged stance on a balance board, and a 10 kg weight plate dropped on the lateral surface of the board, creating a sudden disturbance, and causing ankle inversion of approximately 15°. The athlete was not warned when the weight plate would drop. The balance board was aligned with the slit, where the weight was released, in order to ensure that the weight plate would fall in the same place (Figure 1).[25] *Note: Video Clip 1, available online, shows how this test was administered.*

Electromyographic signals were sampled at a frequency of 2000 Hz and filtered with a band-pass range of 20-450 Hz. Any activities higher than three standard deviations values added to average value for the rest root mean square (RMS) was considered a reactive muscle contraction. The signal generated by the vibration of the 5th metatarsal was considered the instant which the highest frequency was perceived.[26]

Dynamic valgus

The drop-jump vertical test was used to assess the dynamic valgus occurring at the knee.[27] Athletes were instructed to drop from a 50 cm tall box, and asked to immediately execute a two-legged maximal vertical jump after dropping. Each subject performed three attempts. It was not considered valid if the athlete jumped instead of dropping or if the individual was clearly out of balance. The test was filmed with a digital camera (Sony Cyber-shot DSCW35; 7.2 megapixels) in the frontal plane, while supported on a tripod, whose center was three meters away from the center of the platform used. The ability to control the hip and to avoid dynamic valgus knee during the test was classified from 0 to 2. The zero (0) indicated no significant lateral tilt of the pelvis, no valgus motion of the knee and no medial/lateral side-to-side movements of knee during performance; therefore, suggesting a good performance. Individuals graded one (1) showed movements combined or in isolation: lateral tilt of pelvis, knee slightly moving into a valgus position and some medial/lateral side-to-side movements of the knee during the movement; therefore, suggesting a reduced performance. The participants graded two (2) performed the following movements combined or in isolation: lateral tilt of the pelvis, knee clearly moving into a valgus position and medial/lateral side-to-side movements of the knee, suggesting a poor performance.[28]

Figure 1. *Setup for inversion perturbation. A 10-kg weight was dropped onto the posterolateral edge of the balance board to create a sudden inversion stress.*

Quadriceps and Hamstring Strength

A strength test was performed with an isokinetic dynamometer (Biodex System 4; Biodex Medical Systems, New York, NY, USA).[29] This test aims to assess muscle torque production at a constant velocity. The results allow the assessment of the hamstrings/quadriceps ratio. Athletes warmed-up on a stationary bike for five minutes. The dynamometer chair was positioned so that the hip was flexed at 85° and the machine axis was aligned with the sagittal plane axis of the knee. Then, the participants were seated in the dynamometer chair and their positions were stabilized with belts placed at the trunk level. Abdomen and thigh belts were firmly fastened, in order to prevent undesired movements. The machine's lever arm was fixed above the medial malleolus. The test protocol consisted of concentric isokinetic assessment at two speeds: 60°/s and 300°/s, with 5 and 15 repetitions respectively, and an interval of 30 seconds for rest. The equipment was calibrated with range of motion starting from a maximum flexion up to a maximum extension of the knee where the reference point was 90° of flexion. The testing limb was weighed at maximal extension (180°) by the equipment to avoid bias caused by gravity. The upper limbs were positioned laterally holding the chair handles. In order to complete the muscle warm-up period and to familiarize with the equipment, participants were asked to perform five knee flexion-extension submaximal repetitions after the procedures for positioning mentioned above.[30]

Statistical Methods

Data were analyzed in the SPSS version 17.0 software with a significance level of $p \leq 0.05$. The Chi-square test was used to analyze the association of nominal variables between groups, and the independent t-test was used to compare the continuous variables. Index of asymmetry (IS) was calculated for all continuous data by the following formula: IS = (non-dominant limb/dominant limb) x 100. Independent t-test was used to analyze the isolated influence of each FMS™ test on the final score.

RESULTS

The sample was composed of 32 runners who were dichotomized into two groups: functional (n = 16) and dysfunctional (n = 16), according to FMS™ scores. There were no drop outs and no significant differences between groups in baseline demographic variables (Table 1).

In the flexibility assessment, the functional group obtained an average of 30.71 ± 8.3 cm, while the dysfunctional group showed 25.51 ± 9.30 cm (p = 0.42). In the myoelectric response time TrA assessment, three participants (18.75%) from the functional group showed responses at the right time, while in the dysfunctional group only two individuals (12.5%) were able to contract before or at the same time as the deltoid. No difference was demonstrated between groups (χ^2 = 0.654; p = 0.57). The assessment of the fibularis longus response time to a sudden inversion perturbation showed that nine participants (56.2%) from the functional group had a contraction in the proper time, while eleven participants (68.8%) from the dysfunctional group reacted in the same period of time (p = 0.19). There was no difference between groups.

In the drop-jump vertical test, the functional group had six individuals (40%) performing with good performance, three participants (20%) performing with reduced performance and six (40%) performing with poor performance. In the dysfunctional group, six participants (42.8%) had a good performance, four participants (28.6%) had a reduced performance, and four (28.6%) had a poor performance. There was no difference between groups (χ^2 = 0.51; p = 0.77).

Index of asymmetry was used to analyze balance. Global stability, index anterior/posterior and index medial/lateral were compared. The global stability statistically differed between groups; however, no significant differences were observed for the anterior/posterior and medial/lateral index. The results are shown in Table 2.

In assessment of muscular strength, muscle strength index of asymmetry for quadriceps, hamstrings and agonist/antagonist ratio at 60° and 300°/s were compared between groups. No differences were detected as observed in Table 3.

Data comparison of individual' scores in FMS™ tests between groups showed that almost all tests influ-

Table 1. *Characteristics of the sample*

Variables		Functional (n=16)	Dysfunctional (n=16)	p
Age (years)		43.38 ± 8.48 [a]	39.19 ± 8.53 [a]	0.71
Gender	**Female**	03 (9.4%)	05 (15.6%)	0.41
	Male	13 (40.6%)	11 (34.4%)	
Weight (kg)		70.81 ± 8.96 [a]	75.81 ± 8.36 [a]	0.11
Height (cm)		168 ± 5 [a]	171 ± 7 [a]	0.28
Motor dominance	**Right-footed**	11 (34.4%)	15 (46.9%)	0.08
	Left-footed	05 (15.6%)	01 (3.1%)	
Injury in last 12 months		06 (37.5%)	11 (68.7%)	0.08
Time experience in running (years)		7.56 ± 3.94 [a]	5.88 ± 3.57 [a]	0.21
Frequency per week		3.31 ± 0.87 [a]	3.44 ± 1.03 [a]	0.71
Distance per week (km)		33.19 ± 10.4 [a]	29.81 ± 9.0 [a]	0.20

[a] Mean ± Standard Deviation.

Table 2. *Comparison outcomes of balance between limbs, using the Biodex Balance System*

Variables	Functional (n=16)	Dysfunctional (n=16)	*p*
Global stability	3.26±26.79 %	31.72±52.69 %	0.02[†]
Index AP[a]	12.74±51.76 %	51.76±98.10 %	0.26
Index ML[b]	5.9±20.64 %	20.64±66.33 %	0.50

[a]AP: Antero/Posterior; [b]ML: Medial/lateral. [†]Significant at $p < 0.05$ level.

Table 3. *Results comparing index of symmetry of isokinetic strength between limbs and agonist/antagonist values to the suggested reference standards*

Variables	Functional (n=16)	Dysfunctional (n=16)	*p*
Quadriceps 60º/s	11.56±10.96 %	12.15±11.7 1%	0.88
Hamstring 60º/s	14.20±17.37 %	8.12±7.32 %	0.20
Quadriceps 300º/s	0.70±8.88 %	3.05±17.70 %	0.45
Hamstring 300º/s	0.20±10.09 %	3.30±19.37 %	0.52
Hamstring / Quadriceps ratio 60º/s	1.61±36.12 %	3.29±22.23 %	0.87
Hamstring / Quadriceps ratio 300º/s	2.10±13.05 %	4.04±32.88 %	0.50

enced in the subject's classification, with the exception of in line lunge and active straight-leg raise test, which showed no significant difference between the groups. The data are shown in Table 4.

DISCUSSION

The findings of this study showed that the groups classified by the total FMS™ score as either functional or dysfunctional did not demonstrate significant differences in the observed biomechanical tests or anthropometric characteristics, and the in-line-lunge and active-strength-leg-raise tests did not influence the FMS™ categorization of this sample.

Sample characterization data, such as age, gender, weight, height and motor dominance were compared between groups and there were no significant differences. There was no association between previous injuries and total FMS™ score. Although no statistically significant difference existed between groups regarding previous injuries, it is important to mention that previous injury approached a statistically significant difference ($p = 0.08$), and this relationship might be significant with a bigger sample size. Further research with bigger sample sizes is necessary to check the relation of these data. Data from training, years of experience in running, weekly frequency, and training volume were not influential factors in the classification of the sample. Despite these findings, some authors have shown an association between increased distance traveled during training and high risk of injury to the lower extremities, as well as lower volume of practice time, previous injuries, duration of each training session, and workout speed. These last two variables were not analyzed in this study.[31-34]

Table 4. *Comparison between the groups regarding the individual scores of the FMS™ tests*

Tests	Functional (n=16)	Dysfunctional (n=16)	*p*
Deep Squat	2.06±0.44	1.56±0.51	0.006
Hurdle Step	2.25±0.44	1.88±0.34	0.01
In line Lunge	2.31±0.47	2.06±0.57	0.20[†]
Shoulder Mobility	2.63±0.50	1.44±0.90	0.001
Active Straight-Leg Raise	2.25±0.85	1.94±0.68	0.26[†]
Trunk Stability Push-up	2.44±0.81	1.31±0.80	0.001
Rotary Stability	1.70±0.48	1.31±0.48	0.03

[†] Not significant at 5% level.

The sit and reach test for flexibility was not different between groups. However, this test of the posterior chain should in theory be similar to the result of the ASLR test, which also evaluates active posterior chain flexibility and thus should have been different between groups. The authors believe that this occurred because one test involves the spine in the procedure and the other does not. The findings of the current study are not in agreement with the findings of a study of 64 US Army soldiers, which showed that the passive flexibility measured by an inclinometer is strongly associated with good performance in FMS™. This discrepancy may be explained because one group was comprised of runners and the other one was comprised of soldiers, and they may have different physical requirements for performance of their chosen activities.[14,35]

The transversus abdominis activation data also showed no association with the classification of functional assessment, agreeing with the findings of Okada, Huxel, Nesser[36] who examined 28 healthy subjects who aimed to determine the relationship between low back stability, FMS™ and performance. The results of the current study demonstrated that abdominal muscular activation was not correlated with functional performance as measured by the FMS™, despite it being present in many of the prevention programs designed to prevent musculoskeletal injuries.[36] The authors think that this occurred because the FMS™ does not examine rapid movements, nor does it attempt to predict runners susceptible to low back pain.

The fibularis longus muscle response time was not associated with the classification of FMS™, even though it has been described it is a risk factor for ankle sprains.[37] The authors think that this occurred because the FMS™ does not examine rapid movements or factors related to muscular activation, nor does it attempt to predict athletes susceptible to ankle sprains. Similar findings occurred with test for dynamic valgus, which showed no difference between the groups in the sample, highlighting again that the FMS™ does not test this type movement. This does not negate the importance of dynamic valgus as a risk factor for development of patellofemoral syndrome or anterior knee pain, which is a common injury among runners,[38] and the results highlight why tests for dynamic valgus should be included in athlete screening.

Body balance was not an important factor between the groups; however, the global stability statistically differed between groups. This could be because of how balance was measured, as that the units (degrees) from the BBS are unique to this testing device and the global measure takes into account both other measures. The current results corroborate with the findings of another study that evaluated dynamic balance in the military where no difference in a measure of balance was found between groups, though the Y-balance test was performed in the aforementioned study instead of BBS®.[35] Although the results of these two studies agree (no difference in balance between groups) the Y-Balance test is not correlated with the BBS®.[39]

The analyzed muscle strength variables showed no differences between groups for body symmetry, indicating that both groups were symmetrical in the measured variables. This finding matches with the findings of a study that used the isokinetic test to dynamically evaluate the peak of torque, motor dominance and balance between agonists and antagonists of runners and compared with a non-athlete population. They concluded that healthy runners have the characteristic symmetry of muscular strength of knee flexors and extensors.[40]

Considering the isolated tests that comprise the FMS™, the in-line lunge and active straight-leg raise had no differences between the groups, suggesting that these two tests do not influence the classification of subjects into functional or dysfunctional groups using total FMS™ scores. A study was conducted comparing the performance of in-line lunge test with plantar pressure distribution, maximum jump height and a 36 m race time in 35 active and healthy subjects. No correlation with these tests was observed, suggesting that the good performance on in line lunge might not have a relation with better functional performance.[41]

Some authors have suggested that the cutoff point (a score of 14) used as standard for FMS™ in some populations may not be suitable for runners and other athletes. The hypothesis of this research was to state that there would be a difference in the results of biomechanical tests between groups, and that individuals classified as good quality movement (as defined by a score > 14) would perform better than individuals who were classified as poor quality (dysfunctional) movement (as defined as a score) lower than 14. The findings of this research showed that no group exhibited better performance on a variety of biomechanical tests, suggesting that the FMS™ may not be a suitable test for assessing risk of injury for this type of athlete, or this cut point may not be suitable for this population as has been suggested by recent studies. This is an important point that requires more detailed investigation.[8,9]

The authors believe that the results found may be due to a small sample size, as well as the incapacity of FMS™ to predict injuries due to the cutoff point not being appropriate for the population assessed in the current study, as the value was originally described for football players. The cutoff point is currently the most contested explanation, and considered a key point for the authors, requiring additional study.[42,43]

CONCLUSION

The results of the current study demonstrated no differences in biomechanical measures between the groups classified as functional or dysfunctional by the total FMS™ scores. This may indicate that the cut off total FMS™ score of 14 may not properly categorize runners. In addition, the in-line lunge and active straight-leg raise tests did not directly influence the classification of individuals in subgroups.

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